

Generalized Analysis of Orographically Modified Winds and Precipitation Observed by Airborne Doppler Radar During Phases I & II of COAST

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LONG TERM GOALS

Accurate short-range forecasts (~0-48 h lead) of significant mesoscale weather disturbances, especially high winds and heavy precipitation, that can accompany landfalling cool-season frontal systems and intervening periods of steadier flow impinging upon steep coastal terrain.

OBJECTIVES

This research seeks to achieve a quantitative, dynamically-based understanding of the perturbed airflow and precipitation fields associated with both quasi-steady onshore flows oceanic frontal systems and steady onshore flows encountering steep coastal terrain. Moreover, by analyzing observations adjacent to topographic barriers of varying geometry and complexity, we aim to identify reproducible phenomena and more general principles governing these interactions. While the capability of mesoscale numerical forecast models to address these problems is still being tested, such models clearly offer great potential for capitalizing upon this improved understanding if critical processes are identified and appropriate model physics/parameterizations are put into place. Emphasis is thus placed upon collection and analysis of specialized observations needed to validate, test and improve mesoscale models. Of particular interest are those processes leading to development of high winds and heavy precipitation over coastal waters, as well as modulation of airflow and precipitation over the adjacent sloped terrain. Data obtained through pilot observational efforts are also evaluated critically to focus hypotheses and improve observational strategies applied in subsequent field programs.

APPROACH

To be readily comparable to output from state-of-the-art mesoscale research models, observations of landfalling storms and associated flow perturbations near steep terrain should be four dimensional and address disparate parameters such as wind velocity and precipitation intensity. A further challenge is

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that these observations be optimally timed and located so as to envelop relatively limited yet dynamically critical periods/regions in which rapidly varying flow and stability interact strongly with underlying orography. An important platform that can be used to meet this challenge is NOAA's Lockheed WP-3D Orion "hurricane hunter" research aircraft, and in particular its tail-mounted scanning Doppler radar. As outlined in our FY95 Annual Report, the NOAA P-3 aircraft was first brought to bear on this problem under of ONR's Coastal Meteorology ARI during "COAST" (Coastal Observations And Simulations with Topography), whose field phase encompassed six research flights conducted during Nov-Dec 1993. Since applicable theory predicts that terrain-induced circulation changes should be strongest and most readily identifiable adjacent to steep barriers, our efforts detailed below have focused on analysis of an intense cold front that was tracked from an initial location ~400 km offshore to within 20 km of abruptly rising coastal terrain along the southern Oregon coast on 8 December 1993. Armed with knowledge from this and other related COAST studies, the PIs worked closely with other ONR-supported investigators to mount a second field data collection effort in Nov-Dec 1995 ("COAST II"), during which the P-3 completed seven additional flights that were successful in obtaining coastally-focused observations of flow and precipitation structure during the passage of both cold- and warm-frontal systems, including several cyclone-induced coastal windstorms. Through a two-pronged effort involving comprehensive case study analysis of Doppler radar and flight level observations and application of a fully non-hydrostatic mesoscale model in a *diagnostic* sense (i.e., to relate these observations to key thermodynamic/microphysical quantities not adequately specified through in situ or remote sensing), we seek to identify and understand processes that lead to the initiation, propagation and decay of mesoscale zones of enhanced winds and precipitation adjacent to and over steep coastal terrain.

WORK COMPLETED

During this reporting period a manuscript entitled "Airborne Doppler Observations of a Landfalling Cold Front Upstream of Steep Coastal Orography" co-authored by the PI and the ONR-supported postdoc (Dr. Cheng-Ku Yu) funded under this proposal was published in *Monthly Weather Review*. Results of this work were presented at the Pacific Northwest Weather Workshop (held February 2000 in Seattle) and in conjunction with a PACJET (Pacific Landfalling Jets Experiment) planning meeting in Boulder during July 2000. Collaborative work with Dr. Brian Colle (now affiliated with SUNY-Stony Brook) continues to evaluate a companion simulation of this episode observed during COAST IOP8 on 1 December 1995. The period covered by this report corresponds to a no-cost extension through July 31, 2000 that was granted to allow payment of page charges for publication of research supported by this grant and for presentation of results at scientific conferences.

RESULTS

The COAST IOP8 study used airborne Doppler radar observations to describe the mesoscale structure and evolution of a cold frontal system as it made landfall on the mountainous coast of Oregon and northern California. This section of coastline constitutes a steep, approximately two-dimensional orographic barrier, and thus stands in marked contrast to our other COAST studies focusing on atmospheric behavior adjacent to a more three-dimensional barrier, viz. as the Olympic Peninsula of western Washington (e.g., Colle et al. 1999). During IOP8 the landfalling cold front exhibited a northeast-southwest orientation and thus intersected the axis of high terrain at an acute angle. The along-barrier pressure gradient and low-level winds were observed to increase with time along the coastal zone, and reached a maximum just as the front made landfall. Stably stratified prefrontal flow was strongly blocked by the coastal orography, resulting in a confluent transition from pervasive

southwesterly winds offshore to a narrow zone of accelerated south-southwesterly flow near the coast, where wind speeds approached 30 m/s at a height of 750 m MSL. Postfrontal flow was much less affected by the topography, probably because of the considerably weaker stratification within the cool airmass. Upstream blocking by the steep coastal terrain also evidently led to modification of precipitation in the vicinity of the front, including the genesis of a narrow cold frontal rainband (NCFR) and nearshore enhancement of two prefrontal precipitation bands. This observed rapid evolution of the NCFR can be explained in terms of observed changes in the prefrontal vertical wind shear, which favored more upright convective ascent as the front neared shore and encountered accelerated along-barrier flow adjacent to the steepest terrain. Additionally, a statistical examination of observed radar reflectivity patterns shows that the intensity of frontal precipitation systematically decreased with distance away from the steep coastal terrain.

IMPACT/APPLICATIONS

Coastal forecasters (e.g. National Weather Service offices and Storm Prediction Center) and scientists at the Naval Research Laboratory are now more aware that considerable changes in frontal convergence and associated precipitation patterns may accompany landfall of maritime frontal systems when the front

RELATED PROJECTS

Close collaborations continue with Dr. Nicholas Bond (Univ. of Washington & NOAA/PMEL), Prof. Cliff Mass (Univ. of Washington) and Dr. James Doyle (Naval Research Laboratory) concerning complementary observational and numerical studies related to this work.

PUBLICATIONS

Colle, B.A., and B.F. Smull, 2000: High-resolution simulations of a landfalling cold front observed during COAST IOP2 (In preparation).

Yu, C.-K., and B.F. Smull, 2000: Airborne Doppler observations of a landfalling cold front upstream of steep coastal orography. *Mon. Wea. Rev.*, **128**, 1577-1603.